January 1995

Physics 30

Grade 12 Diploma Examination

Alberta
EDUCATION

January 1995

Physics 30

Grade 12 Diploma Examination

Description

Time: 2.5 h. You may take an additional 0.5 h to complete the examination.

Total possible marks: 70

This is a **closed-book** examination consisting of

- 37 multiple-choice and 12 numerical-response questions each with a value of one mark
- 2 written-response questions with a combined value of 21 marks

This examination contains sets of related questions. A set of questions may contain multiple-choice and/or numerical-response and/or written-response questions.

Tear-out data sheets are included at the back of this booklet.

The perforated pages at the back of this booklet may be torn out and used for your rough work. No marks will be given for work done on the tear-out pages.

Instructions

- Fill in the information required on the answer sheet and the examination booklet as directed by the presiding examiner.
- You are expected to provide your own scientific calculator.
- Use only an HB pencil for the machine-scored answer sheet.
- If you wish to change an answer, erase **all** traces of your first answer.
- Consider all numbers used in the examination to be the result of a measurement or observation.
- Do not fold the answer sheet.
- The presiding examiner will collect your answer sheet and examination booklet and send them to Alberta Education.
- Read each question carefully.
- Now turn this page and read the detailed instructions for answering machine-scored and written-response questions.

Multiple Choice

- Decide which of the choices **best** completes the statement or answers the question.

- Locate that question number on the separate answer sheet provided and fill in the circle that corresponds to your choice.

Example

This examination is for the subject of

A. biology
B. physics
C. chemistry
D. science

Answer Sheet

Ⓐ ● Ⓒ Ⓓ

Numerical Response

- Record your answer on the answer sheet provided by writing it in the boxes and then filling in the corresponding circles.

- If an answer is a value between 0 and 1 (e.g., 0.25), then be sure to record the 0 before the decimal place.

- **Enter the first digit of your answer in the left-hand box and leave any unused boxes blank.**

Examples

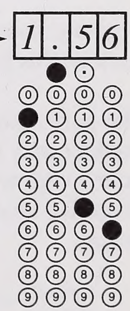
Calculation Question and Solution

If a 121 N force is applied to a 77.7 kg mass at rest on a frictionless surface, the acceleration of the mass would be ________ m/s^2.
(Round and record your answer to three digits on the answer sheet.)

$$a = \frac{F}{m}$$

$$a = \frac{121\ \text{N}}{77.7\ \text{kg}} = 1.5572716$$

Record 1.56 on the answer sheet ⟶

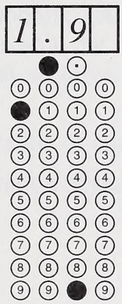


Calculation Question and Solution

A microwave of wavelength 16 cm has a frequency of $\boldsymbol{b} \times 10^9$ Hz. The value of $\boldsymbol{b}$ is _________.
(Round and record your answer to two digits on the answer sheet.)

$f = c/\lambda$
$= (3.00 \times 10^8 \text{ m/s})/(0.16 \text{ m})$
$f = 1.875 \times 10^9$ Hz

Record 1.9 on the answer sheet →



Written Response

- Write your answers in the examination booklet as neatly as possible.
- For full marks, your answers must be well organized and address **all** the main points of the question.
- Relevant scientific, technological, and/or societal concepts and examples must be identified and explicit.
- Descriptions and/or explanations of concepts must be correct and reflect pertinent ideas, calculations, and formulas.
- Your answers **should be** presented in a well-organized manner using complete sentences, correct units, and significant digits where appropriate.

Do not turn the page to start the examination until told to do so by the presiding examiner.

1. $F = \frac{kq_1q_2}{R^2}$ is an expression of the law attributed to

A. Ohm

B. Newton

C. Coulomb

D. Kirchoff

2. An initially uncharged ebonite (hard rubber) rod is rubbed with an initially uncharged piece of cat's fur. As a result, the fur becomes positively charged and the ebonite becomes equally charged negative. This **best** illustrates

A. the law of conservation of charge

B. the law of conservation of mass

C. Coulomb's law

D. Ohm's law

Use the following information to answer the next question.

Factors Related to Point Charges

I	the magnitude of the charge
II	the sign of the charge
III	the distance from the charge
IV	the magnitude of the test charge

3. Which factors are needed to determine the magnitude and direction of the electric field $|\vec{E}|$ due to a point charge?

A. I and IV only

B. I, III, and IV only

C. I, II, and III only

D. I, II, III, and IV

Use the following information to answer the next six questions.

The Photocopier

A typical copier has an aluminum drum that is coated with a thin layer of the semiconductor selenium. The drum is rotated through a container of toner. The toner consists of tiny charged plastic beads coated with carbon grains. The coated beads are attracted to the charged areas of the selenium layer on the drum but not to the areas where the charge has dispersed. A sheet of paper is then pressed against the drum and the coated beads are transferred to the paper. The paper is heated and the beads melt, attaching the carbon to the paper to form the image.

Numerical Response

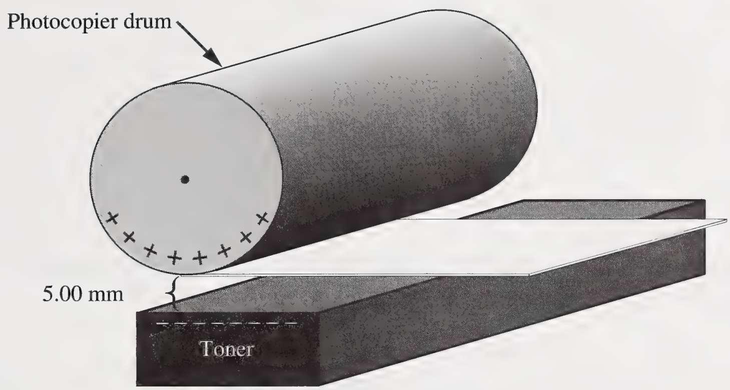
1. A photocopier requires 0.750 kilowatts when printing. To print 500 sheets on both sides at a rate of one side per second, the energy used by the photocopier, expressed in scientific notation, is $b \times 10^{w}$ J.
The value of b is ___________ .
(Round and record your answer to three digits on the answer sheet.)

Numerical Response

2. When determining what to charge for printing on a photocopier, one of the "hidden" costs involved is the cost of electricity. After the copier is warmed up, it uses an average of 6.82 A while operating on a 110 V power supply. If the cost of electricity is 0.00200¢ per kJ, the cost to print 1020 copies at a rate of one copy per second would be ___________ ¢.
(Round and record your answer to three digits on the answer sheet.)

Use this additional information to answer the next four questions.

Photocopier



Assume that the beads of toner (dry ink) and letters on the drum act as point charges. The charge on each bead of toner is -6.40×10^{-16} C and the average charge on the part of the drum with the image of the letter copied is $+7.10 \times 10^{-13}$ C.

Numerical Response

3. When the toner and the drum are separated by 5.00 mm, the force of attraction between the letter and the toner bead, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-13}$ N. The value of $\boldsymbol{b}$ is ____________.
(Round and record your answer to three digits on the answer sheet.)

Numerical Response

Use your answer from ***Numerical Response 3*** *to answer* ***Numerical Response 4****.*

4. Each coated bead in the photocopier has an average mass of 1.92×10^{-15} kg. The acceleration of a bead toward the drum, expressed in scientific notation, is $\boldsymbol{b} \times 10^{w}$ m/s^2. Ignoring the presence of gravity, the value of $\boldsymbol{b}$ is ____________.
(Round and record your answer to three digits on the answer sheet.)

4. Suppose the charge on each bead of toner is reduced to -1.60×10^{-16} C. To have the same force of attraction between a letter and a toner bead as in **Numerical Response 3**, the distance separating the drum and the toner must be changed to

A. 1.30 mm

B. 2.50 mm

C. 1.00 mm

D. 2.00 mm

5. If the drum is positive and the toner is negative, the direction of the electric field at a point halfway between the drum and the toner is

A. in the same direction of the drum rotation

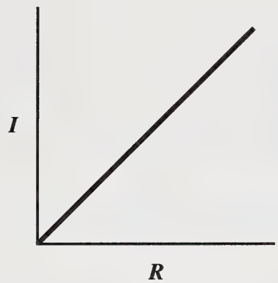
B. in the opposite direction of the drum rotation

C. from the drum to the toner

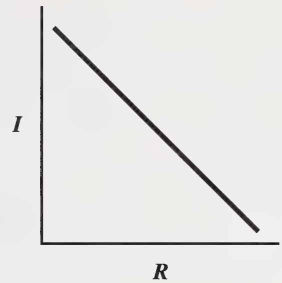
D. from the toner to the drum

6. Which graph shows the relationship between current I and resistance R for resistors that obey Ohm's law and are connected to a constant potential difference?

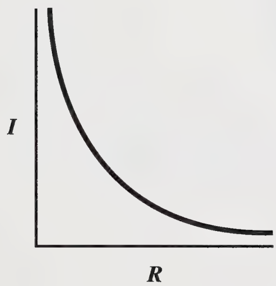
A.



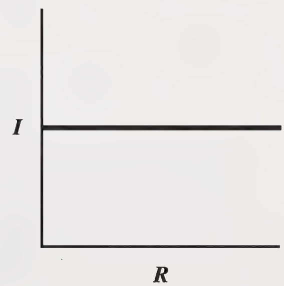
B.



C.

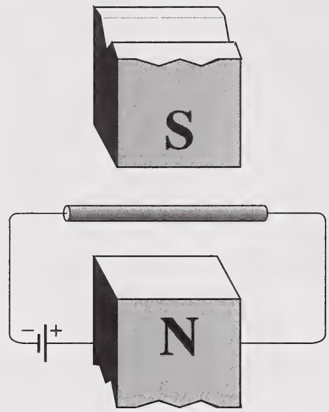


D.



Use the following information to answer the next question.

A Current in an External Magnetic Field



7. The direction of the magnetic force exerted on the current-carrying wire is

A. toward the top of the page
B. toward the bottom of the page
C. into the plane of the page
D. out of the plane of the page

Use the following information to answer the next two questions.

$$S = Bvl$$

A wire of length l (with a speed v) passes perpendicularly through an external magnetic field B.

8. When the magnetic field strength is 0.235 T, the speed of the wire is 10.7 m/s and the length of the wire is 27.8 cm. The numerical value of *S* in SI base units is

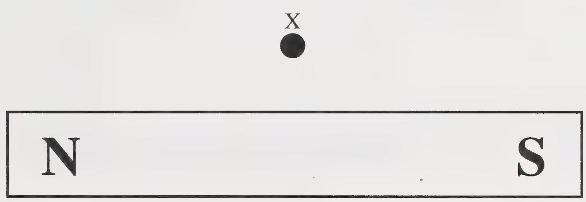
A. 0.699
B. 2.51
C. 69.9
D. 251

9. The appropriate SI unit for *S* is

A. N
B. V
C. N/C
D. kg•m/s

Use the following information to answer the next question.

Magnetic Field of a Bar Magnet



10. The direction of the magnetic field at point **X** is toward the

A. bottom of the page
B. right of the page
C. left of the page
D. top of the page

Use the following information to answer the next question.

An alpha particle and an electron travelling at the same speed enter perpendicularly into a uniform magnetic field.

11. Which of the following statements concerning the forces on the particles is true?

A. The force on the alpha particle is greater because it carries the higher charge.
B. The force on the alpha particle is greater because its mass is greater.
C. The force on the electron is greater because its mass is smaller.
D. The force on the particles is equal.

Numerical Response

5. A certain charged particle moves in a path of radius 25.0 cm, in a uniform magnetic field. If the speed of the particle is doubled and the magnetic field strength is quadrupled, the new radius is ___________ cm.
(Round and record your answer to three digits on the answer sheet.)

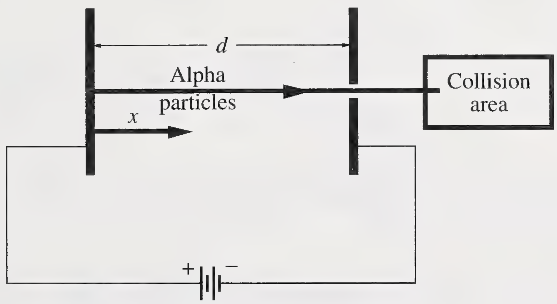
12. In a Millikan experiment, a small sphere with a mass of 8.16×10^{-16} kg is suspended between plates that are 2.00 cm apart. This sphere is maintained at a potential difference of 1.00×10^{2} V. What is the net charge on the small sphere?

A. 1.60×10^{-19} C
B. 1.60×10^{-18} C
C. 8.00×10^{-17} C
D. 4.00×10^{-12} C

Use the following information to answer the next three questions.

Linear Accelerator

The following is a simplification of what takes place when charged particles are accelerated and collisions take place. To accelerate alpha particles, charged parallel plates may be used. The magnitude of the electric field between two charged parallel plates at a **fixed** distance d apart can be calculated for different distances x from the positive plate.



In the collision area, the incoming alpha particles moving at 8.07×10^{6} m/s collide with other alpha particles that are at rest. Assume that each collision involves two alpha particles in an inelastic collision that form a new $^{8}_{4}Be$ (beryllium) nucleus.

13. What is the final momentum of the new $^{8}_{4}Be$ nucleus?

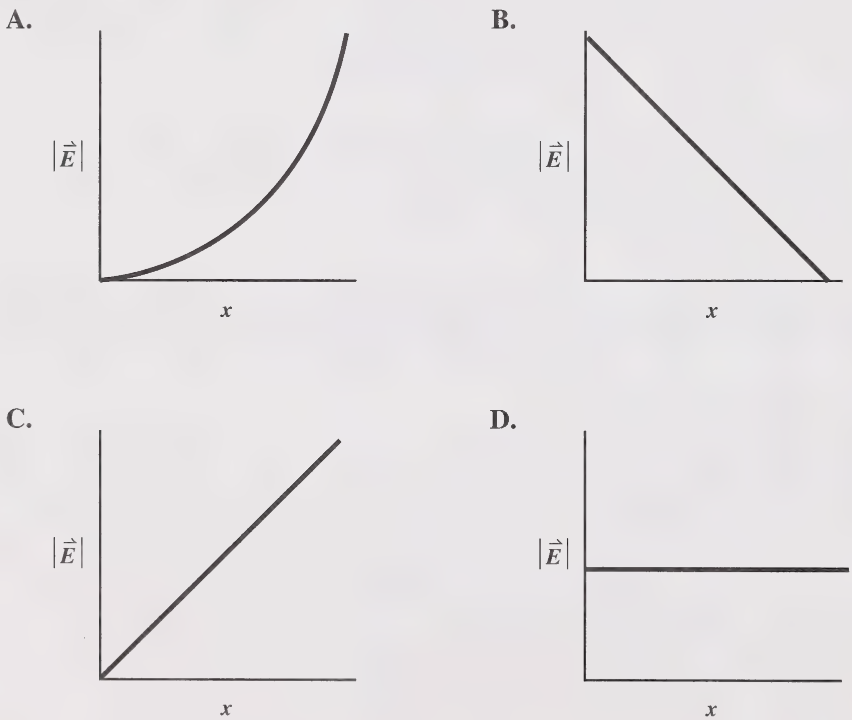
A. 1.07×10^{-19} kg•m/s
B. 5.37×10^{-20} kg•m/s
C. 2.68×10^{-20} kg•m/s
D. 1.35×10^{-20} kg•m/s

Numerical Response

Use your answer from ***Multiple Choice 13*** *to answer* ***Numerical Response 6.***

6. Some initial kinetic energy is carried over to the kinetic energy of the new particle $^{8}_{4}\text{Be}$. This energy is not available for creating new particles or for putting the nucleus into an excited state. The kinetic energy of the $^{8}_{4}\text{Be}$ nucleus, expressed in scientific notation, is $\boldsymbol{b} \times 10^{-w}$ J. The value of $\boldsymbol{b}$ is ____________ .
(Round and record your answer to three digits on the answer sheet.)

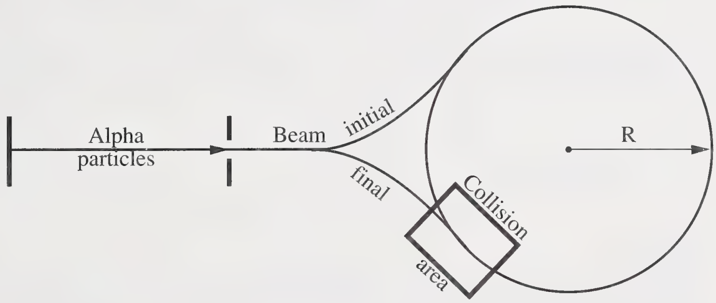
14. The graph that represents the magnitude of the electric field as a function of the distance x from the positive plate is



Use the following information to answer the next two questions.

Zero Momentum Collisions

In order to have the maximum initial kinetic energy available for the creation of new particles, physicists design equipment to create head-on collisions with particles having the same magnitude of momentum. Thus the total momentum of the colliding particles is zero.



To bend the beam of alpha particles, external magnetic fields may be used.

15. To make an alpha particle that is moving at a speed of 8.07×10^6 m/s follow a path of radius 10.0 m, how strong must the magnetic field be?

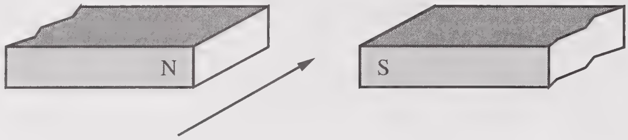
A. 5.37×10^{-20} T
B. 1.68×10^{-2} T
C. 3.35×10^{-2} T
D. 8.07×10^{5} T

16. The magnitude of the force exerted on a charged particle by a magnetic field depends on the

A. sign of the charge
B. mass of the particle
C. velocity of the particle
D. perpendicular depth of the field

Use the following information to answer the next question.

Alpha Particles in Magnetic Fields



A horizontal beam of alpha particles is projected perpendicularly between a pair of magnetic poles.

17. The ions will be deflected

A. upward
B. downward
C. toward the north pole
D. toward the south pole

Numerical Response

7. A transformer has 60 turns on the primary coil and 300 turns on the secondary coil. It is used to supply a motor that requires a current of 2.54 A. The current in the primary coil is ___________ A.
(Round and record your answer to three digits on the answer sheet.)

Use the following information to answer the next question.

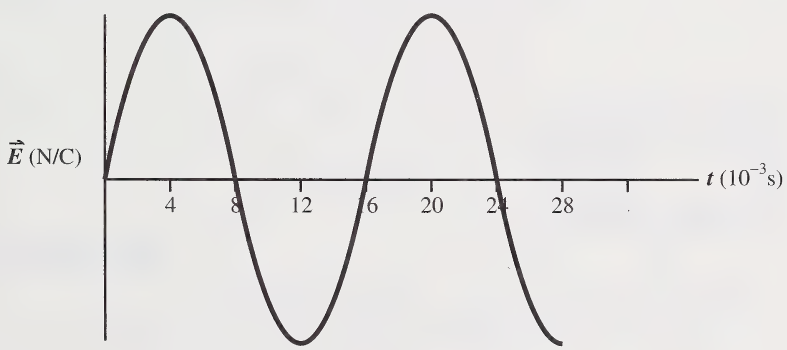
I	Oscillating magnet
II	Accelerating proton
III	Steady electric current
IV	Stationary electron

18. The phenomena that produce an electromagnetic wave are

A. I and II
B. I and III
C. II and IV
D. III and IV

Use the following information to answer the next question.

The electric field strength near a large transformer was measured over a period of time. The results are graphed below.



Numerical Response

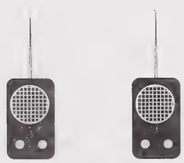
8. The wavelength of the source, expressed in scientific notation, is $b \times 10^{w}$ m.
The value of b is ____________ .
(Round and record your answer to three digits on the answer sheet.)

19. Which of the following regions of the electromagnetic spectrum do **not** overlap?

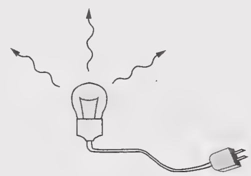
A. X-ray and ultraviolet
B. Radar and microwave
C. Microwave and infrared
D. Gamma rays and ultraviolet

Use the following information to answer the next question.

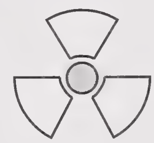
The following pieces of equipment are devices that produce electromagnetic radiation over a wide range of frequencies.



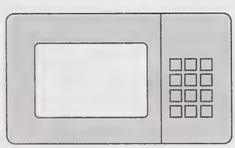
I
Walkie Talkies



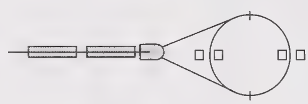
II
Lamps



III
Radioactive sources



IV
Microwave ovens



V
Particle accelerators

20. Identify the correct order in which the devices must be placed, so that the frequency produced is arranged from the lowest to the highest.

A. I, IV, II, III, V
B. II, I, IV, V, III
C. IV, I, II, V, III
D. II, IV, I, III, V

Use the following information to answer the next four questions.

Researchers have developed a reliable blue laser that could revolutionize optical data storage. It is now possible to focus blue light on a smaller spot so that data can be stored five times more densely than with the more conventional infrared laser. Blue light oscillates with a period of 1.53×10^{-15} s.

21. Which quality of blue light makes it possible to store data five times more densely?

A. Blue light is in the visible region of the electromagnetic spectrum.
B. Blue light has a shorter wavelength.
C. Blue light has a lower frequency.
D. Blue light refracts less.

Numerical Response

9. The wavelength of blue light, expressed in scientific notation, is $b \times 10^{-w}$ m. The value of b is __________ .
(Round and record your answer to three digits on the answer sheet.)

Numerical Response

10. The wavelength of a photon produced by an infrared laser is 4.23×10^{-5} m. The energy of a photon of infrared radiation, expressed in scientific notation, is $b \times 10^{-w}$ eV. The value of b is __________ .
(Round and record your answer to three digits on the answer sheet.)

22. The momentum of a photon of blue light is directly proportional to its

A. wavelength
B. frequency
C. rest mass
D. velocity

Use the following information to answer the next three questions.

A common application of the quantum theory in technology is the development of automatic door openers and burglar alarms, which are operated by **electric eyes**. An electromagnetic beam shines across a door opening onto a photovoltaic cell. This causes electrons to be emitted, creating a current that flows in a circuit. When the beam is broken, the current stops and a mechanism is triggered to open a door or sound an alarm.

Common Photovoltaic Cells		Common Electromagnetic Beam Sources	
Type	Threshold Frequency (Hz)	Type	Wavelength (m)
Sodium	5.60×10^{14}	Microwave	3.00×10^{-4}
Zinc	9.68×10^{14}	Infrared	9.00×10^{-7}
Tin	1.20×10^{15}	Visible (Green Light)	5.00×10^{-7}
Iron	1.13×10^{15}	Ultraviolet	1.00×10^{-7}

23. Which of the given electromagnetic beam sources would be able to activate **all** of the given photovoltaic cells listed?

A. Ultraviolet
B. Microwave
C. Ultraviolet and Visible
D. Microwave and Infrared

24. Which combination of electromagnetic beam sources and photovoltaic cells would emit electrons with the greatest kinetic energy?

A. Microwave beam with a sodium photovoltaic cell

B. Ultraviolet beam with a sodium photovoltaic cell

C. Microwave beam with an iron photovoltaic cell

D. Ultraviolet beam with an iron photovoltaic cell

25. A newly designed burglar alarm uses a photocell with a threshold frequency of 8.0×10^{14} Hz. When a light with a frequency of 1.05×10^{15} Hz is directed on the cell, what is the kinetic energy of the released photoelectrons?

A. 4.4 eV

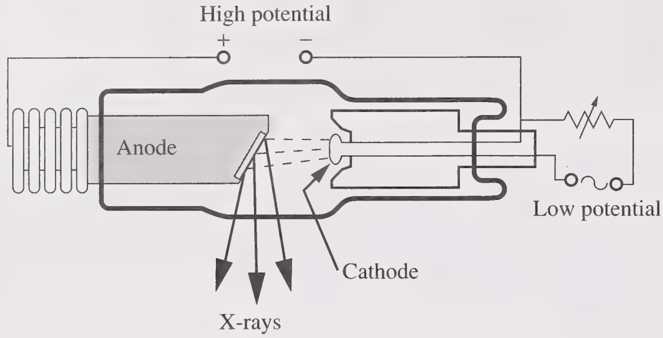
B. 3.3 eV

C. 1.7 eV

D. 1.0 eV

Use the following diagram to answer the next five questions.

X-ray Tube



26. The reason for enclosing the anode and cathode of an X-ray tube in a vacuum is that the

A. X-rays travel faster in a vacuum
B. air would allow too much heat to escape
C. vacuum is required to focus the X-rays
D. electron beam has difficulty travelling through air

27. If the potential difference between the anode and the cathode is increased, the X-rays produced will have

A. shorter wavelengths and greater penetrating power
B. longer wavelengths and greater penetrating power
C. shorter wavelengths and less penetrating power
D. longer wavelengths and less penetrating power

28. While keeping the voltage constant and varying the current between the cathode and the anode, an X-ray technician controls the

A. penetrating power of the X-rays
B. wavelength of the X-rays
C. frequency of the X-rays
D. intensity of the X-rays

29. The energy absorbed by living matter exposed to X-ray radiation can be quite devastating. The greatest amount of energy absorbed would occur when the

A. time of exposure is long and the rate of exposure is low
B. time of exposure is long and the rate of exposure is high
C. time of exposure is short and the rate of exposure is low
D. time of exposure is short and the rate of exposure is high

30. X-rays are sometimes used to kill cancer cells in patients. However, the procedure must be used with great caution because

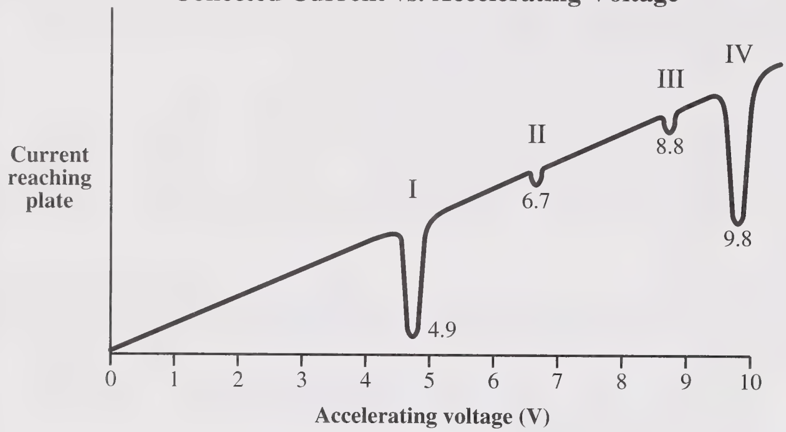
A. X-rays also destroy healthy cells in the patient
B. X-rays are produced by high energy electrons
C. hospital workers cannot be protected from X-rays
D. electrical and magnetic fields cannot be used to control X-rays

Use the following information to answer the next three questions.

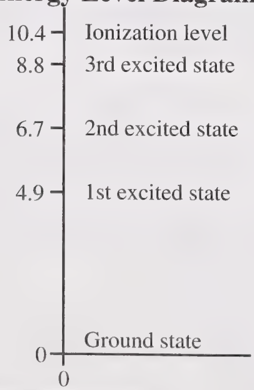
In a Franck-Hertz experiment, free electrons are emitted from the cathode of a low pressure tube containing mercury vapour. The free electrons strike the mercury vapour atoms in the tube. The accelerating voltage on the electrons leaving the cathode is gradually increased.

Below is a graph showing the relationship between the collected current transmitted through the mercury vapour and the accelerating voltage. An energy level diagram for mercury is also shown.

Collected Current vs. Accelerating Voltage



Energy Level Diagram



31. When the accelerating voltage on an electron is 3.0 V, the electron will

A. separately strike and excite two mercury atoms to the first excited state
B. strike a mercury atom and excite it to the second excited state
C. strike a mercury atom and excite it to the first excited state
D. pass directly to the anode without exciting any mercury atoms

32. Which region on the graph represents the effect on an electron that excites a single mercury atom to the third excited state?

A. I
B. II
C. III
D. IV

33. Region IV on the graph represents electrons that

A. struck two mercury atoms separately and excited each atom to the first excited state
B. struck several mercury atoms and excited them to the second excited state
C. struck several mercury atoms and excited them to the first excited state
D. passed directly to the anode without exciting any mercury atoms

---

34. From the spectrum given off by a young star, several extremely bright lines stand out from all the rest. The wavelength of one of the intense bright lines is 656.21 nm. This wavelength represents an energy change in the atom of

A. 3.03×10^{19} J

B. 3.29×10^{18} J

C. 3.29×10^{-18} J

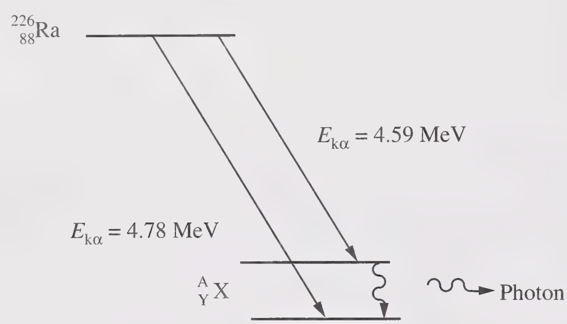
D. 3.03×10^{-19} J

35. An electron in the hydrogen atom changes from the $n = 5$ state to the $n = 2$ state. According to the Bohr model, the electron moves toward the nucleus a distance of

A. $3r_1$
B. $5r_1$
C. $21r_1$
D. $25r_1$

Use the following information to answer the next three questions.

In the decay of $^{226}_{88}Ra$, two groups of alpha particle energies are observed.



The difference in kinetic energy between the alpha particles can be accounted for by the release of a photon.

Numerical Response

11. The wavelength of the emitted photon, expressed in scientific notation, is $b \times 10^{-w}$ m. The value of b is ____________ .
(Round and record your answer to three digits on the answer sheet.)

Numerical Response

12. The half-life of ${}^{226}_{88}Ra$ is 1.62×10^3 y. If 2.04 mg of radium were present, the mass of radium remaining after 4.86×10^3 y would be, expressed in scientific notation, $\boldsymbol{b} \times 10^{-w}$ mg. The value of $\boldsymbol{b}$ is __________ .
(Round and record your answer to three digits on the answer sheet.)

Use the additional information to answer the next question.

Statement I	Radium always has an atomic number of 88.
Statement II	The radium nucleus always contains 88 neutrons.

36. Which of the following responses correctly describes the two statements?

A. Both statements are true, and one statement can be explained by the other.
B. Both statements are true, but neither statement can be used to explain the other.
C. Statement I is true, and statement II is false.
D. Statement I is false, and statement II is false.

---

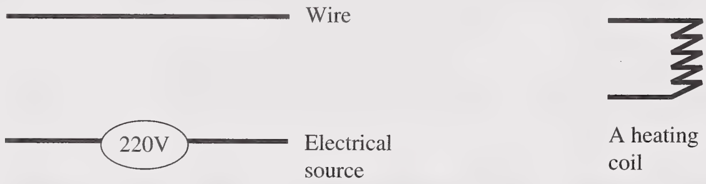
37. Radioactive materials are frequently used as **tracers** to monitor systems in the human body. To test the function of a patient's kidney, a small volume of solution containing a radioactive isotope with an activity of 3600 disintegrations per minute is injected into the bloodstream. After two hours, the activity of 20 cm^3 of blood is three disintegrations per minute. If the half-life of the isotope is one hour, the estimated volume of blood inside the patient is

A. 7500 cm^3
B. 6000 cm^3
C. 4500 cm^3
D. 3000 cm^3

Written Response – 10 marks

Use the following information to answer written-response question 1.

Hot water in a domestic residence is produced by heating water in a tank. The heating source in many hot water tanks is provided by 220 V electrical coils that are placed in the tank. Each of the electrical coils has a resistance of 15 Ω.



1. **a.** Using the symbols above, draw the circuit diagram that would use two coils to heat the water in the shortest possible time.

b. What current is provided by the 220 V source to the two heating coils?

For Department Use Only

c. What is the power consumed by each heating coil?

Use this additional information to answer the next question.

The amount of energy needed to heat water is given by the formula $E = mc\Delta T$, where m is the mass of water, c is the specific heat capacity of water, and ΔT is the change in temperature. The specific heat of water is 4.2×10^3 J/(°C•kg).

d. How long in minutes will it take the two heating coils to raise the temperature of a tank containing 160 kg of water by 1.0° C? (If you were unable to determine the amount of consumed power in part **c**, use the hypothetical value $P = 3.55 \times 10^3$ W.)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21

Use the following information to answer written-response question 2.

Reproduction of a Police Accident Report

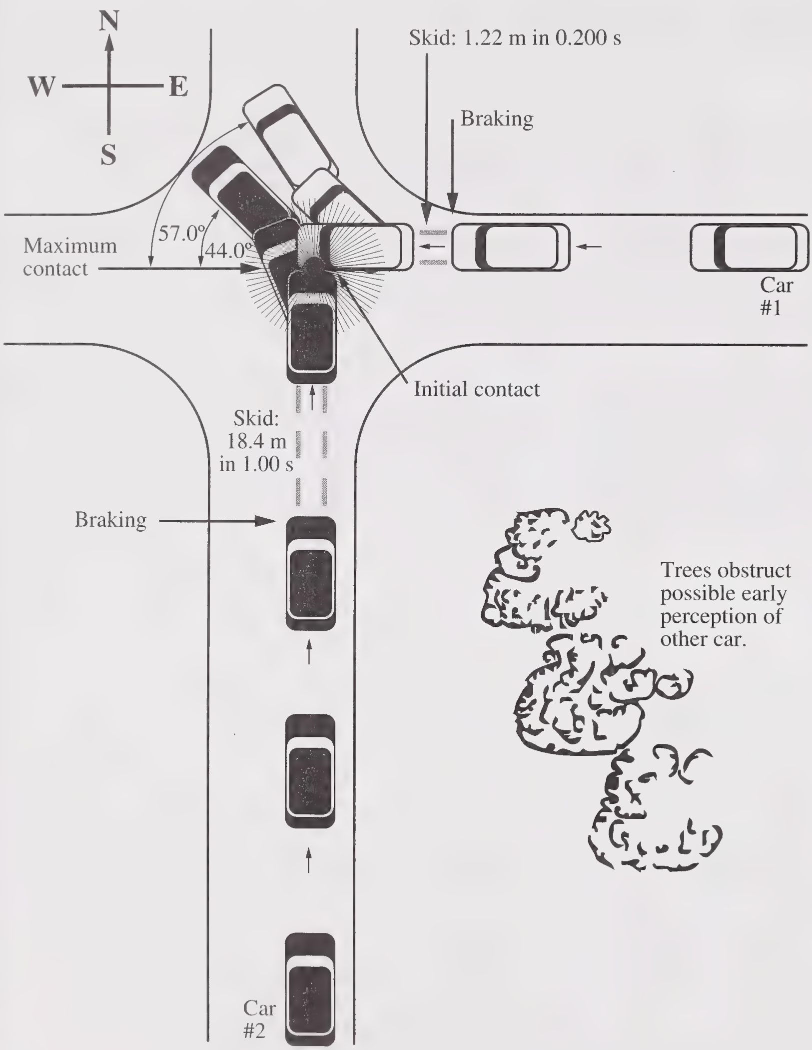


Diagram is not to scale.

Written Response – 11 marks

2. After measuring and evaluating skid marks, police were able to determine that Car #1, of mass 765 kg, was travelling at 70.0 km/h just after the impact. Car #2, of mass 1100 kg, was determined to be moving at 41.0 km/h just after impact. In analyzing this accident scene, it is important for police to establish the velocity of each car just before impact.

Describe in detail and **show how** the police investigator would calculate the velocities of both cars just before collision.

Note: A maximum of 8 marks will be awarded for the physics used to solve this problem. A maximum of 3 marks will be awarded for the effective communication of your response.

(You may continue your answer on page 28.)

You have now completed the examination.
If you have time, you may wish to check your answers.

Tear-out Page

PHYSICS DATA SHEETS

CONSTANTS

Gravity, Electricity, And Magnetism

Acceleration Due to Gravity or Gravitational Field Near Earth	a_g or $g = 9.81\ \text{m/s}^2$ or $9.81\ \text{N/kg}$
Gravitational Constant	$G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$
Mass of Earth	$M_e = 5.98 \times 10^{24}\ \text{kg}$
Radius of Earth	$R_e = 6.37 \times 10^6\ \text{m}$
Coulomb's Law Constant	$k = 8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2$
Electron Volt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$
Elementary Charge	$e = 1.60 \times 10^{-19}\ \text{C}$
Index of Refraction of Air	$n = 1.00$
Speed of Light in Vacuum	$c = 3.00 \times 10^8\ \text{m/s}$

Atomic Physics

Energy of an Electron in the 1st Bohr Orbit of Hydrogen	$E_1 = -2.18 \times 10^{-18}\ \text{J}$ or $-13.6\ \text{eV}$
Planck's Constant	$h = 6.63 \times 10^{-34}\ \text{J}\cdot\text{s}$
Radius of 1st Bohr Orbit of Hydrogen	$r_1 = 5.29 \times 10^{-11}\ \text{m}$
Rydberg's Constant for Hydrogen	$R_H = 1.10 \times 10^7/\text{m}$

Particles

	Rest Mass	Charge
Alpha Particle	$m_\alpha = 6.65 \times 10^{-27}\ \text{kg}$	α^{2+}
Electron	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	e^-
Neutron	$m_n = 1.67 \times 10^{-27}\ \text{kg}$	n^0
Proton	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	p^+

Trigonometry And Vectors

$$\sin\theta = \frac{opposite}{hypotenuse}$$

$$\cos\theta = \frac{adjacent}{hypotenuse}$$

$$\tan\theta = \frac{opposite}{adjacent}$$

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

$$c^2 = a^2 + b^2 - 2ab\cos C$$

For any Vector $\vec{R}$

$$R = \sqrt{R_x^{\,2} + R_y^{\,2}}$$

$$\tan\theta = \frac{R_y}{R_x}$$

$$R_x = R\cos\theta$$

$$R_y = R\sin\theta$$

Prefixes Used With SI Units

Prefix	Symbol	Exponential Value
pico	p	10^{-12}
nano	n	10^{-9}
micro	µ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}

Prefix	Symbol	Exponential Value
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deka	da	10^{1}

EQUATIONS

Kinematics

$$\vec{v}_{\text{ave}} = \frac{\vec{d}}{t}$$

$$\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{t}$$

$$\vec{d} = \vec{v}_{\text{i}}t + \frac{1}{2}\vec{a}t^2$$

$$\vec{d} = \vec{v}_{\text{f}}t - \frac{1}{2}\vec{a}t^2$$

$$\vec{d} = \left(\frac{\vec{v}_{\text{f}} + \vec{v}_{\text{i}}}{2}\right)t$$

$$v_{\text{f}}^2 = v_{\text{i}}^2 + 2ad$$

Dynamics

$$\vec{F} = m\vec{a}$$

$$\vec{F}t = m\Delta\vec{v}$$

$$\vec{F}_{\text{g}} = m\vec{g}$$

$$F_{\text{f}} = \mu F_{\text{N}}$$

$$\vec{F}_{\text{s}} = -k\vec{x}$$

$$F_{\text{g}} = \frac{Gm_1m_2}{r^2}$$

$$g = \frac{Gm_1}{r^2}$$

$$F_{\text{c}} = \frac{mv^2}{r}$$

$$F_{\text{c}} = \frac{4\pi^2mr}{T^2}$$

Momentum and Energy

$$\vec{p} = m\vec{v}$$

$$W = Fd$$

$$W = \Delta E = Fd\cos\theta$$

$$P = \frac{W}{t} = \frac{\Delta E}{t}$$

$$E_{\text{k}} = \frac{1}{2}mv^2$$

$$E_{\text{p}} = mgh$$

$$E_{\text{p}} = \frac{1}{2}kx^2$$

Waves and Light

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$T = \frac{1}{f}$$

$$v = f\lambda$$

$$\frac{\lambda_1}{2} = l; \quad \frac{\lambda_1}{4} = l$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

$$\lambda = \frac{xd}{nl}$$

$$\lambda = \frac{d\sin\theta}{n}$$

$$m = \frac{h_{\text{i}}}{h_0} = \frac{-d_{\text{i}}}{d_0}$$

$$\frac{1}{f} = \frac{1}{d_0} + \frac{1}{d_{\text{i}}}$$

EQUATIONS

Electricity and Magnetism

$$F_e = \frac{kq_1q_2}{r^2}$$

$$|\vec{E}| = \frac{kq_1}{r^2}$$

$$\vec{E} = \frac{\vec{F}_e}{q}$$

$$|\vec{E}| = \frac{V}{d}$$

$$V = \frac{\Delta E}{q}$$

$$R = R_1 + R_2 + R_3$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$I_{eff} = 0.707\, I_{max}$$

$$V = IR$$

$$P = IV$$

$$I = \frac{q}{t}$$

$$F_m = IlB_{\perp}$$

$$F_m = qvB_{\perp}$$

$$V = lvB_{\perp}$$

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

$$V_{eff} = 0.707\, V_{max}$$

Atomic Physics

$$hf = E_{k_{max}} + W$$

$$W = hf_0$$

$$E_{k_{max}} = qV_{stop}$$

$$E = hf = \frac{hc}{\lambda}$$

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$E_n = \frac{1}{n^2}E_1$$

$$r_n = n^2 r_1$$

$$N = N_0\left(\frac{1}{2}\right)^n$$

Quantum Mechanics and Nuclear Physics

$$E = mc^2$$

$$p = \frac{h}{\lambda}$$

$$p = \frac{hf}{c};\quad E = pc$$

Tear-out Page

No marks will be given for work done on this page.

mm 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210

Tear-out Page

No marks will be given for work done on this page.

mm 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210

Physics 30
January 1995

Name

Apply Label With Student's Name

Physics 30

Name: (Last Name) (Legal First Name) Date of Birth: Y M D Sex:

Permanent Mailing Address: (Apt./Street/Ave./P.O. Box) (Village/Town/City) (Postal Code)

School Code: School: Signature:

No Name

Apply Label Without Student's Name

Physics 30

For Department Use Only

Marker ID

Marker ID

Marker ID

Marker ID

286949

PHYSICS 30

DIPLOMA EXAMINATION

JANUARY 1995

Multiple Choice
and
Numerical Response
Key

Draft
Written Response
Scoring Guide

Written Response Question 2 – Holistic Scoring Guide
Reporting Category: Physics COMMUNICATION

When marking COMMUNICATION, the marker should consider how effectively the response describes in detail how the police investigator would calculate the velocities of both cars just before collision.

Score	Criteria
3 Excellent	The response: • is well organized and the explaination of the two-dimensional conservation of momentum aspects of the problem to clear • describes in detail the strategy in a logical manner demonstrating consistency of thought • uses physics vocabulary appropriately and a precise, explicit relationship exists between the explanation and diagrams • explicitly states momentum formula and trigonometric functions used • may have a mathematical error present, but it does not hinder the understanding of either the strategy or the solution • expresses the final velocities of each car (magnitude and direction) using the appropriate units and correct number of significant digits (internal consistency)
2 Satisfactory	The response: • is organized and in the attempt to explain the two-dimensional conservation of momentum aspects of the problem errors sometimes affect the clarity of the explanation • describes the strategy but details are general and/or sometimes lacking, leaving it somewhat open to interpretation • uses physics vocabulary, however, it is sometimes misused; and an implicit relationship exists between explanation and diagrams (if used) • usually states momentum formula and trigonometric functions used, however, they may be inferred by analyzing the calculations • likely has mathematical errors present that may hinder the understanding of either the strategy or the solution • expresses the final velocities of each car (direction may be missing); as well, the units may not be appropriate orthe number of significant digits may be incorrect
1 Poor	The response: • lacks organization and the attempt to explain the two-dimensional aspect of the problem is not evident, however, an attempt to explain the conservation of momentum aspect of the problem is evident; errors may be present that affect the clarity of the explanation • describes a strategy that provides little or no detail • uses physics vocabulary, however, it is often misused and there is weak relationship between the explanation and diagrams (if used) • may not state the momentum formula, however, it is likely that it can be inferred by analyzing the calculations • may have mathematical errors that hinder the understanding of the strategy and/or the solution • expresses the final answers, if present, in magnitude only, units are inappropriate, and/or the number of significant digits are incorrect
0	The response: • is not organized and there is little attempt to explain any aspect of the problem • does not describe a strategy to solve the problem • uses little or no physics vocabulary, however, if present, it is misused and there is no relationship between the explanation, if present, and diagrams (if used) • may state the momentum formula but it does not contribute towards the solution • is confusing and/or frustrating to the reader • has very little written
NR	No response given.

Written Response Question 2 – Holistic Scoring Guide

Reporting Category: Physics CONTENT

When marking CONTENT, the marker should consider how effectively the response uses physics concepts, knowledge, and skills to show how the police investigator would calculate the velocities of both cars just before collision.

Score	Criteria
4 Standard of Excellence	The response: • addresses the major concept of conservation of momentum • uses an appropriate strategy that reflects thorough understanding of the two-dimensional aspect of the problem • correctly uses momentum formula and trigonometric functions; substitution is correct • provides the velocity of each car just before collision that is consistent with their strategy
3	The response: • addresses the major concept of conservation of momentum • uses an appropriate strategy that reflects a good understanding of the two-dimensional aspect of the problem • correctly uses momentum formula, however, either the use of the trigonometric functions and/or substitution into formula or functions may be flawed • provides the velocity of each car just before collision that may be inconsistent with their strategy
2 Acceptable Standard	The response: • addresses the major concept of conservation of momentum • uses a strategy that reflects an understanding of the two-dimensional aspect of the problem • correctly uses momentum formula, however, use of the trigonometric functions are either incorrect or incomplete, as well substitution into formula and/or functions are flawed • provides the velocity of each car just before collision that may be inconsistent with their strategy
1	The response: • may indirectly address the major concept of the conservation of momentum • uses a strategy that reflects little or no understanding of the two-dimensional aspect of the problem; the strategy used may treat the problem as one-dimensional • may use momentum formula, however, the use may be inappropriate or incomplete as well substitution into formula may be flawed • provides momentums of the cars but may fail to solve for the velocities just before impact
0	The response: • shows little or no evidence that momentum is conserved • uses a strategy that is inappropriate or there is little or no evidence of a strategy • does not provide momentums or velocities of the cars
NR	No response is given.

Written Response – 11 marks

2. After measuring and evaluating skid marks, police were able to determine that Car #1, of mass 765 kg, was travelling at 70.0 km/h just after the impact. Car #2, of mass 1100 kg, was determined to be moving at 41.0 km/h just after impact. In analyzing this accident scene, it is important for police to establish the velocity of each car just before impact.

Describe in detail and **show how** the police investigator would calculate the velocities of both cars just before collision.

Note: A maximum of 8 marks will be awarded for the physics used to solve this problem. A maximum of 3 marks will be awarded for the effective communication of your response.

Use the following information to answer written-response question 2.

Reproduction of a Police Accident Report

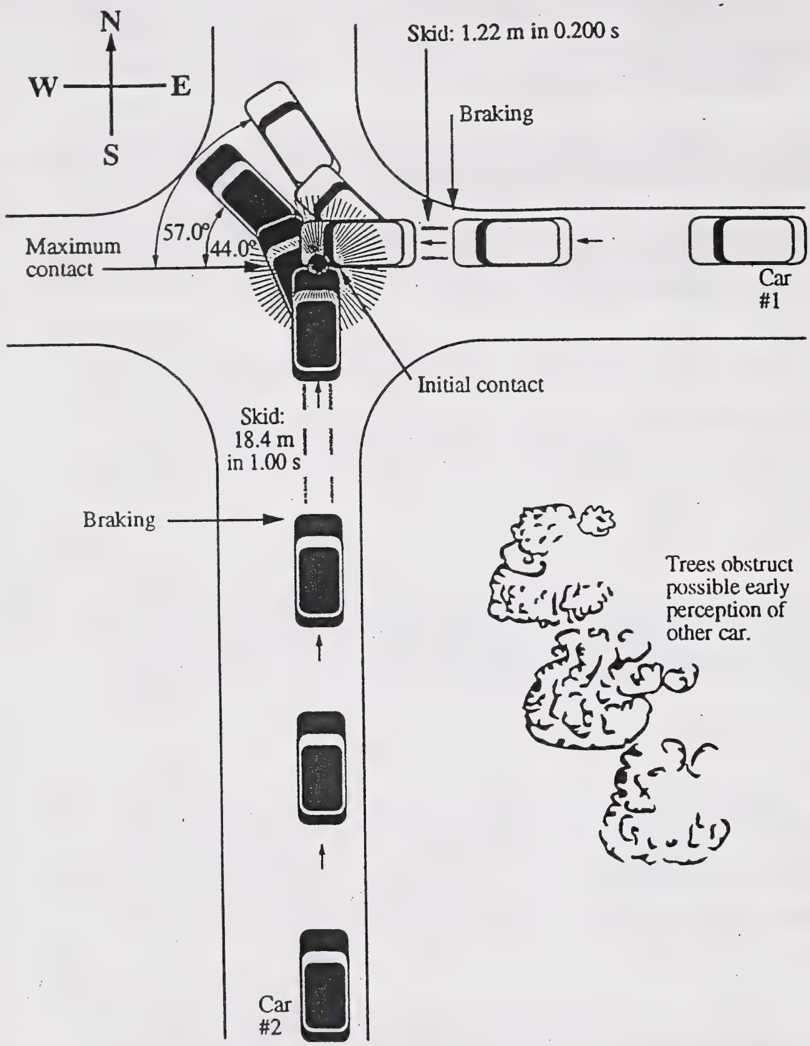


Diagram is not to scale.

Special Case
Using the hypothetical value $P = 3.55 \times 10^3$ W
Solution is the same as for parallel circuits (see page vii **Parallel Circuit**)

There are eight checks (checks 14, 15, 16, 17, 18, 19, 20, and 21) for this part:

14. stating $E = mc\Delta T$
15. calculating $E = 6.72 \times 10^5$ J
16. stating $P = VI$
17. calculating $P = 1.606 \times 10^3$ W
    (or using intermediate values $P = 1.6133333 \times 10^3$ W)
18. stating $P = \frac{E}{t}$ or equivalent
19. correct substitutions throughout
20. calculating $t = 4.1843088 \times 10^2$ s
    (or using intermediate values $t = 4.1652893 \times 10^2$ s)
21. converting to $t = 7.0$ min
    (or using intermediate values $t = 6.9$ min)

Note: Checks 16 and 17 can be awarded if the student brings in their answer from part c and then multiplies by 2.
Also, if the solution uses the hypothetical value of $P = 3.55 \times 10^3$ W, checks 16 and 17 cannot be awarded.

Convert checks to marks and record.

Checks	Marks
20 or 21	10
18 or 19	9
16 or 17	8
14 or 15	7
12 or 13	6
10 or 11	5
8 or 9	4
6 or 7	3
4 or 5	2
2 or 3	1
0 or 1	0

Use this additional information to answer the next question.

> The amount of energy needed to heat water is given by the formula $E = mc\Delta T$, where m is the mass of water, c is the specific heat capacity of water, and ΔT is the change in temperature. The specific heat of water is 4.2×10^3 J/(°C•kg).

d. How long in minutes will it take the two heating coils to raise the temperature of a tank containing 160 kg of water by 1.0° C? (If you were unable to determine the amount of consumed power in part **c**, use the hypothetical value $P = 3.55 \times 10^3$ W.)

Energy needed to heat water.

$$E = mc\Delta T$$

$$E = (160 \text{ kg})\left(\frac{4.2 \times 10^3 \text{ J}}{°\text{C} \cdot \text{kg}}\right)(1.0° \text{ C})$$

$$E = 6.72 \times 10^5 \text{ J}$$

Power produced by two coils.

Using rounded values.

$$P = VI$$

$$P = (220 \text{ V})(7.3 \text{ A})$$

$$P = 1.606 \times 10^3 \text{ W}$$

Using intermediate values.

$$P = (220 \text{ V})(7.333333 \text{ A})$$

$$P = 1.6133333 \times 10^3 \text{ W}$$

Time needed to heat water.

$$P = \frac{W}{t} \quad \text{work = energy needed}$$

$$P = \frac{E}{t}$$

$$t = \frac{E}{P}$$

$$t = \frac{(6.72 \times 10^5 \text{ J})}{(1.606 \times 10^3 \text{ W})}$$

$$t = \left(4.1843088 \times 10^2 \text{s}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$$

$$t = 7.0 \text{ min}$$

Using intermediate values.

$$t = \frac{(6.72 \times 10^5 \text{ J})}{(1.6133333 \times 10^3 \text{ W})}$$

$$t = \left(4.1652893 \times 10^2 \text{s}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$$

$$t = 6.9 \text{ min}$$

Note: If the student doubles the value for P in part **c** (8.1×10^2 W), and uses either 1.62×10^3 W or 1.6×10^3 W, then $t = 6.9$ min

c. What is the power consumed by each heating coil?

Potential drop across each coil is half the electrical source.

$$P = VI$$

$$P = \left(\frac{220 \text{ V}}{2}\right)(7.3 \text{ A})$$

$$P = 8.1 \times 10^2 \text{ W}$$

(using 7.3333333 A produces the same power value of 8.1×10^2 W)

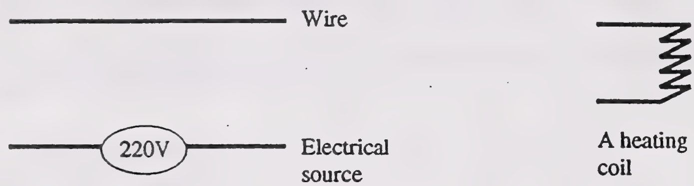
There are five checks (checks 9, 10, 11, 12, and 13) for this part:

9. stating $P = VI$
10. stating that the potential drop across each coil is half the electrical source or that the power produced by each coil is half the total power
11. dividing voltage by 2
12. substitution
13. an answer $P = 8.1 \times 10^2$ W

Written Response – 10 marks

Use the following information to answer written-response question 1.

Hot water in a domestic residence is produced by heating water in a tank. The heating source in many hot water tanks is provided by 220 V electrical coils that are placed in the tank. Each of the electrical coils has a resistance of 15 Ω.



1. a. Using the symbols above, draw the circuit diagram that would use two coils to heat the water in the shortest possible time.

Method 2 – Series Circuit Solution

Checks 1, 2, and 3 are not available to the series circuit solution. Leaving scoring boxes 1, 2, and 3 blank.

b. What current is provided by the 220 V source to the two heating coils?

$$R = R_1 + R_2$$
$$R = 15\ \Omega + 15\ \Omega$$
$$R = 30\ \Omega$$
$$V = IR$$
$$I = \frac{V}{R}$$
$$V = \frac{220\ \text{V}}{30\ \Omega}$$
$$I = 7.3333333\ \text{A}$$
$$I = 7.3\ \text{A}$$

There are five checks (checks 4, 5, 6, 7, and 8) for this part:

4. stating $R = R_1 + R_2$
5. calculating $R = 30\ \Omega$
6. stating $V = IR$ or equivalent
7. correct substitutions throughout
8. an answer $I = 7.3$ A

Special Case

Using the hypothetical value $P = 3.55 \times 10^3$ W

$$t = \frac{(6.72 \times 10^5\ \text{J})}{2(3.55 \times 10^3\ \text{W})}$$

$$t = 9.4647887 \times 10^1\ \text{s}$$

$$t = \left(9.4647887 \times 10^1\ \text{s}\right)\left(\frac{1\ \text{min}}{60\ \text{s}}\right)$$

$$t = 1.5774647 \times 10^0\ \text{min}$$

$$t = 1.58\ \text{min}$$

There are eight checks (checks 14, 15, 16, 17, 18, 19, 20, and 21) for this part:

14. stating $E = mc\Delta T$
15. calculating $E = 6.72 \times 10^5$ J
16. stating $P = VI$
17. calculating $P = 6.38 \times 10^3$ W
 (or using intermediate values $P = 6.4533333 \times 10^3$ W)
18. stating $P = \frac{E}{t}$ or equivalent
19. correct substitutions throughout
20. calculating $t = 1.0532915 \times 10^2$ s
 (or using intermediate values $t = 1.0413232 \times 10^2$ s)
21. converting to $t = 1.8$ min
 (or using intermediate values $t = 1.7$ min)

Note: Checks 16 and 17 can be awarded if the student brings in their answer from part c and then multiplies by 2.
Also, if the solution uses the hypothetical value of $P = 3.55 \times 10^3$ W, checks 16 and 17 cannot be awarded.

Convert checks to marks and record.

Checks	Marks
20 or 21	10
18 or 19	9
16 or 17	8
14 or 15	7
12 or 13	6
10 or 11	5
8 or 9	4
6 or 7	3
4 or 5	2
2 or 3	1
0 or 1	0

Use this additional information to answer the next question.

The amount of energy needed to heat water is given by the formula $E = mc\Delta T$, where m is the mass of water, c is the specific heat capacity of water, and ΔT is the change in temperature. The specific heat of water is 4.2×10^3 J/(°C·kg).

d. How long in minutes will it take the two heating coils to raise the temperature of a tank containing 160 kg of water by 1.0° C? (If you were unable to determine the amount of consumed power in part **c**, use the hypothetical value $P = 3.55 \times 10^3$ W.)

Energy needed to heat water.

$$E = mc\Delta T$$

$$E = (160\text{ kg})\left(\frac{4.2 \times 10^3\text{ J}}{°\text{C} \cdot \text{kg}}\right)(1.0°\text{ C})$$

$$E = 6.72 \times 10^5\text{ J}$$

Power produced by two coils.

Using rounded values.

$$P = VI$$

$$P = (29\text{ A})\,(220\text{ V})$$

$$P = 6.38 \times 10^3\text{ W}$$

Using intermediate values.

$$P = VI$$

$$P = (29.333333\text{ A})\,(220\text{ V})$$

$$P = 6.4533333 \times 10^3\text{ W}$$

Time needed to heat water.

$$P = \frac{W}{t} \quad \text{work = energy needed}$$

$$P = \frac{E}{t}$$

$$t = \frac{E}{P}$$

$$t = \frac{(6.72 \times 10^5\text{ J})}{(6.38 \times 10^3\text{ W})}$$

$$t = 1.0532915 \times 10^2\text{ s}$$

$$t = \left(1.0532915 \times 10^2\text{ s}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)$$

$$t = 1.7554858 \times 10^0\text{ min}$$

$$t = 1.8\text{ min}$$

Using intermediate values.

$$t = \frac{(6.72 \times 10^5\text{ J})}{(6.4533333 \times 10^3\text{ W})}$$

$$t = 1.0413223 \times 10^2\text{ s}$$

$$t = \left(1.0413223 \times 10^2\text{ s}\right)\left(\frac{1\text{ min}}{60\text{ s}}\right)$$

$$t = 1.7355371 \times 10^0\text{ min}$$

$$t = 1.7\text{ min}$$

b. What current is provided by the 220 V source to the two heating coils?

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R} = \frac{1}{15} + \frac{1}{15}$$

$$\frac{1}{R} = 7.5\ \Omega$$

$$V = IR \qquad I = \frac{V}{R}$$

$$I = \frac{220\ \text{V}}{7.5\ \Omega} = 2.93 \times 10^1\ \text{A}$$

$$I = 29\ \text{A}$$

There are <u>five</u> checks (checks 4, 5, 6, 7, and 8) for this part:

4. stating $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$
5. calculating $R = 7.5\ \Omega$
6. stating $V = IR$ or equivalent
7. correct substitutions throughout
8. an answer $I = 29$ A

c. What is the power consumed by each heating coil?

Current through each coil is half the total current.

$$P = VI$$

$$= (220\ \text{V})\left(\frac{29.3\ \text{A}}{2}\right)$$

$$P = 3.2 \times 10^3\ \text{W}$$

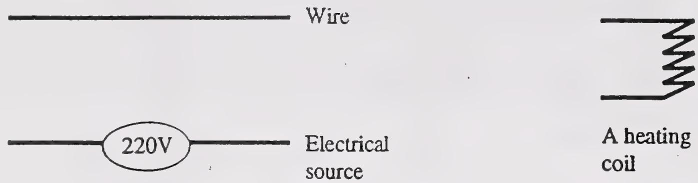
There are <u>five</u> checks (checks 9, 10, 11, 12, and 13) for this part:

9. explaining that the current through each coil is half the total current or that the power produced by each coil is half the total power
10. stating $P = VI$ or equivalent
11. dividing either the total current in the circuit or the total power produced by both coils by two or equivalent
12. substituting correctly
13. an answer $P = 3.2 \times 10^3$ W

Written Response – 10 marks

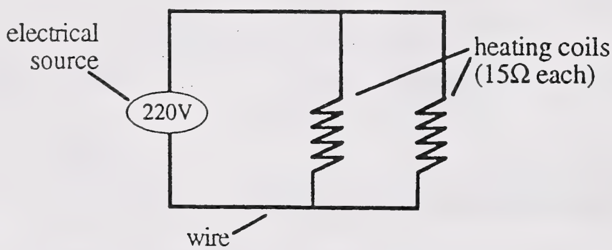
Use the following information to answer written-response question 1.

Hot water in a domestic residence is produced by heating water in a tank. The heating source in many hot water tanks is provided by 220 V electrical coils that are placed in the tank. Each of the electrical coils has a resistance of 15 Ω.



1. a. Using the symbols above, draw the circuit diagram that would use two coils to heat the water in the shortest possible time.

Method 1 – Parallel Circuit Solution



There are three checks (checks 1, 2, and 3) for this part:

1. drawing a circuit (must have two coils and electrical source)
2. heating coils are placed in parallel
3. labelled diagram (labelling of the wire is not necessary and a switch added to the circuit is acceptable if done correctly)

PHYSICS 30 DIPLOMA EXAMINATION 3260951
WRITTEN-RESPONSE SCORING GUIDE

General Comments

1. These are **sample** answers: different approaches may be used.

2. All written-response questions involving calculations must start with a formula statement, and the substituted values written down in a subsequent step. If a number with **no** unit is substituted, assume that the omitted unit is the appropriate SI base unit.

3. Do not double penalize a student. If the calculations to a part yield a wrong answer and that answer is used correctly in a following part, award full marks for the following part.

4. To be awarded full marks, final answers must include appropriate units and be expressed to the correct number of significant digits. In question 1, one check can be withheld from part a, b, c or d (to a maximum of two checks for the question) for either omitting appropriate units or expressing significant digits incorrectly in the final answer.

5. If numerical answers to previous parts of the same question are used to create answers to new parts, intermediate values or final answers may be used. However, if the handling of significant digits is not consistent, the student may lose one check.

PHYSICS 30 – 951
Multiple Choice and Numerical-response Key

1	C	NR-8	4.80
2	A	19	D
3	C	20	A
NR-1	7.50	21	B
NR-2	1.53	NR-9	4.59
NR-3	1.63	NR-10	2.94
*NR-4	8.49	22	B
4	B	23	A
5	C	24	B
6	C	25	D
7	C	26	D
8	A	27	A
9	B	28	D
10	B	29	B
11	A	30	A
NR-5	12.5	31	D
12	B	32	C
13	B	33	A
**NR-6	1.08	34	D
~~14~~	~~D~~ DELETE	35	C
15	B	NR-11	6.54
16	C	NR-12	2.55
17	B	36	C
NR-7	12.7	37	B
18	A		

* Although the correct answer to **NR 4** is 8.49 based on **NR 3**'s answer of 1.63, there are many acceptable answers for **NR 4** dependent on the answer to **NR 3**. As a result, answers to **NR 4** should be considered individually using either the rounded or unrounded answer to **NR 3**.

** Although the correct answer to NR 6 is 1.08 based on **MC 13**'s answer of **B**, other answers are acceptable for **NR 4** dependent on the answers of **A, C,** and **D** for **MC 13**. As a result, answers to NR 6 should be considered individually using either the rounded, **A, B, C, D** answers to **MC 13**, or the unrounded answers to **MC 13**.